



# Noise Performance of the CrIS Instrument On-orbit

**SUOMI NPP SDR Science and Validated Product Maturity Review**

SDL, Exelis, NOAA STAR results

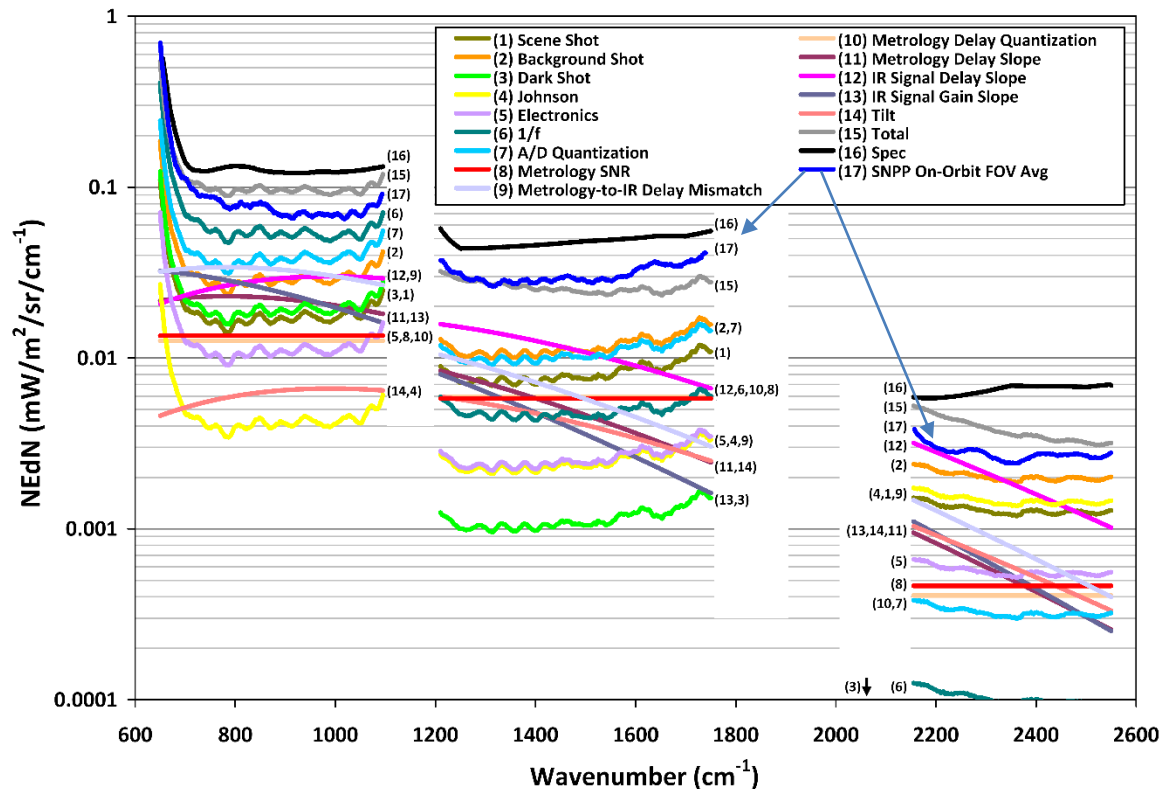
Vladimir Zavyalov presenting

December 18-20, 2013

# Outline

1. Noise sources and on-orbit real spectra NEdN
2. CrIS on-orbit noise performance as compared to TVAC ground test and heritage AIRS and IASI instruments
3. On-orbit NEdN trend. NEdN stability over different orbital positions (North Pole, Tropics, and South Pole)
4. Small seasonal, spatial, and orbital NEdN variations.
5. NEdN FOV1 anomaly observed in July-September 2013
6. Imaginary spectra NEdN as a diagnostic tool to monitor instrument health
7. Orbital behavior of the imaginary NEdN
8. Conclusion.

# CrIS Instrument Noise Sources

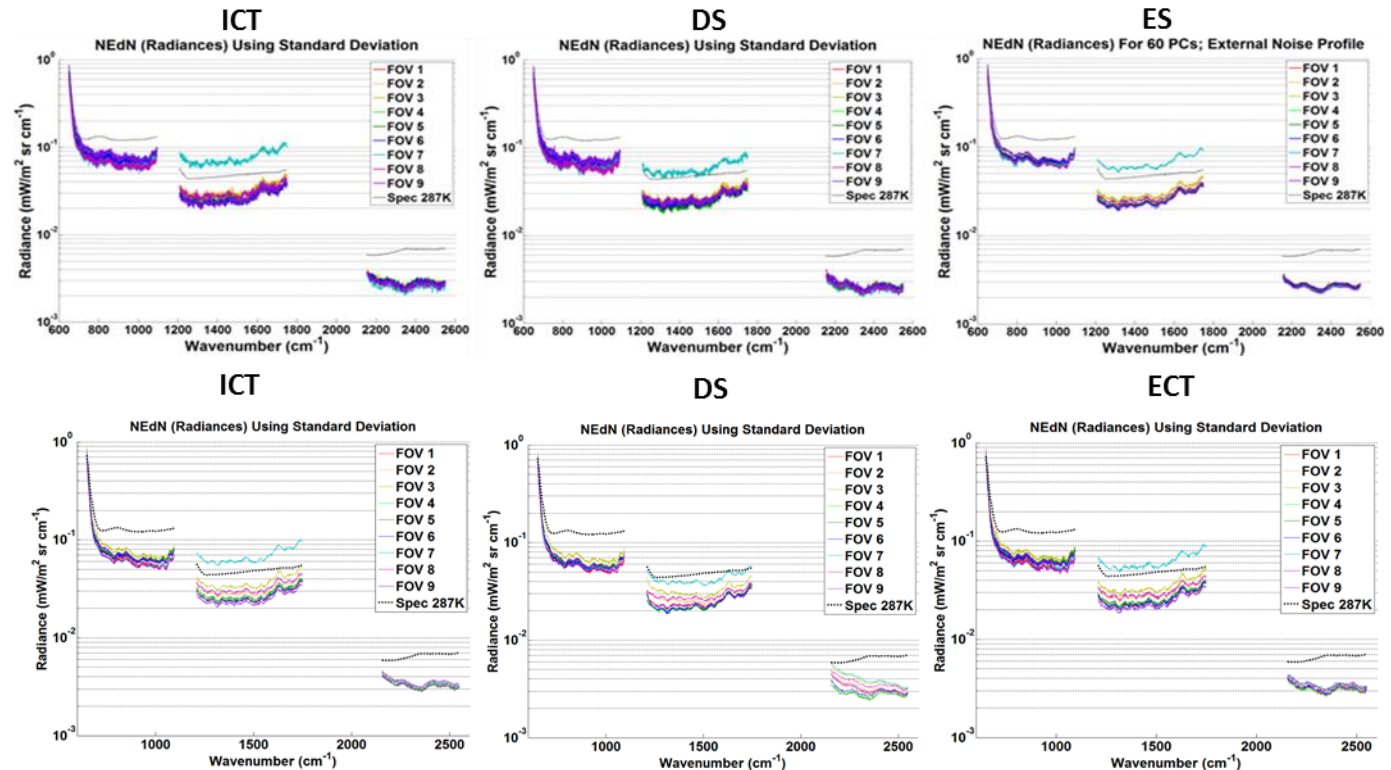


- Exelis CrIS NEΔN model and simulations: 1-7 detector and electronics noise; 8-14 interferogram distortion noise (may lead to spectrally correlated noise component)
- Major contributors: LWIR- 1/f noise; MWIR and SWIR - background shot and IR signal delay slope noise
- On-orbit background shot noise dominates in MWIR and SWIR spectral bands. Note, under external vibration interferometer induced noise dominates – characteristic slope (12)

# On-orbit NEdN vs TVAC4

On-orbit  
January 10, 2013

TVAC 4, MN  
 $T_{ECT}=287K$



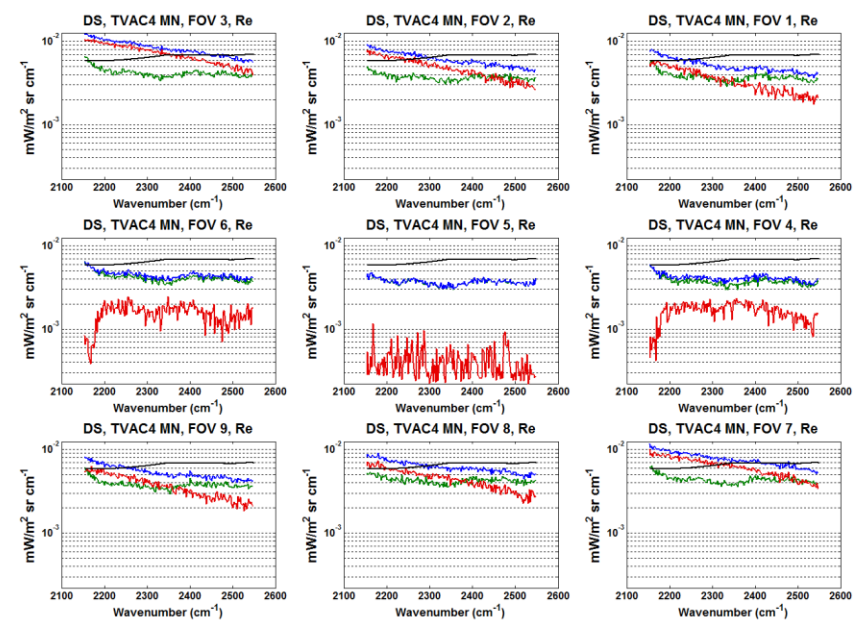
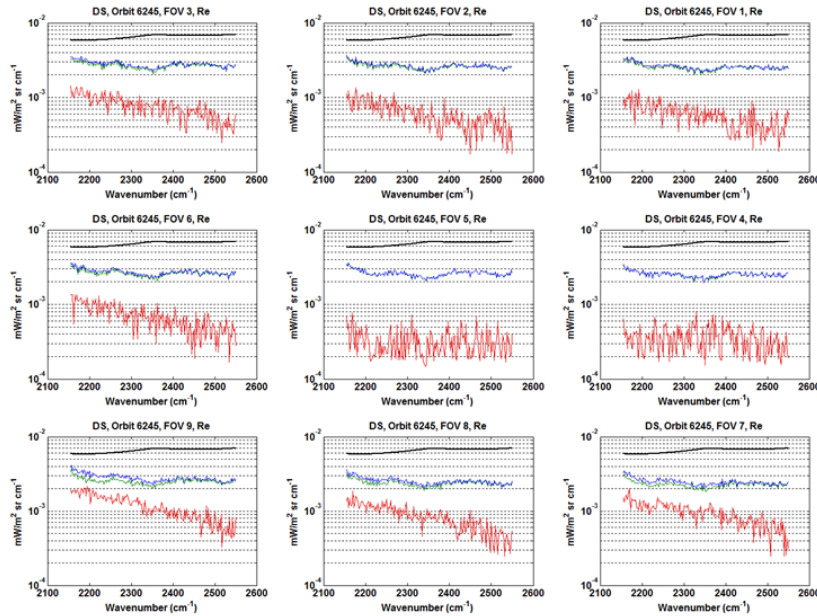
- NEdN in all spectral channels and FOVs (except MWIR FOV7) is well within spec
- On orbit NEdN is practically the same as during TVAC4 ground test
- MWIR FOV7 is slightly out of spec from TVAC4 test probably due to migrating impurities in the IR detector interface (may change after warm-up/cool-down cycle).



# Correlated noise contribution: SWIR DS-worse case

SWIR DS:  
Orbit #6245 January 10, 2013

SWIR DS: TVAC4 MN

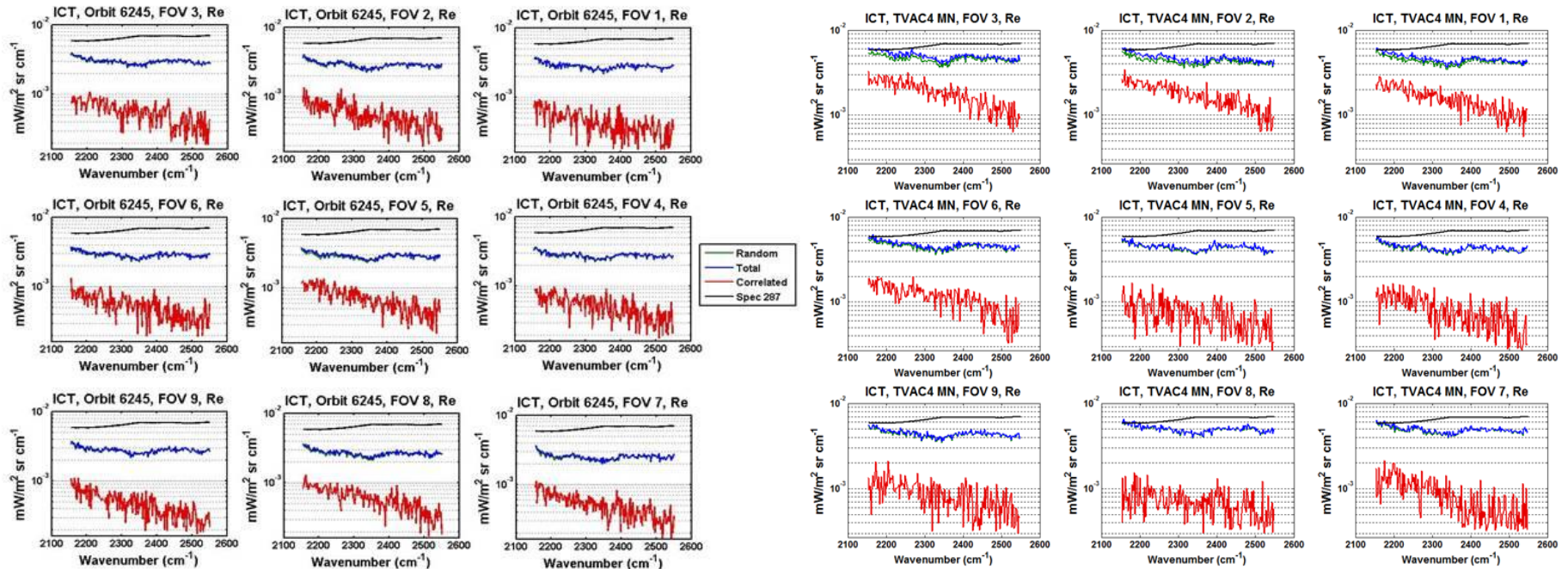


- On-orbit NEdN exhibit significantly lower correlated noise contribution. During TVAC4 test additional vibration from the test equipment was present
- Vibration test and NEdN simulations conclusions:
  - SWIR NEdN is most sensitive to the external vibration
  - DS is most sensitive to the external vibration as compared to the ICT and ECT
  - Corner FOVs (1,3,7,9) are most susceptible to the vibration
- PCA technique was used for correlated noise estimations

# Correlated noise contribution: SWIR ICT

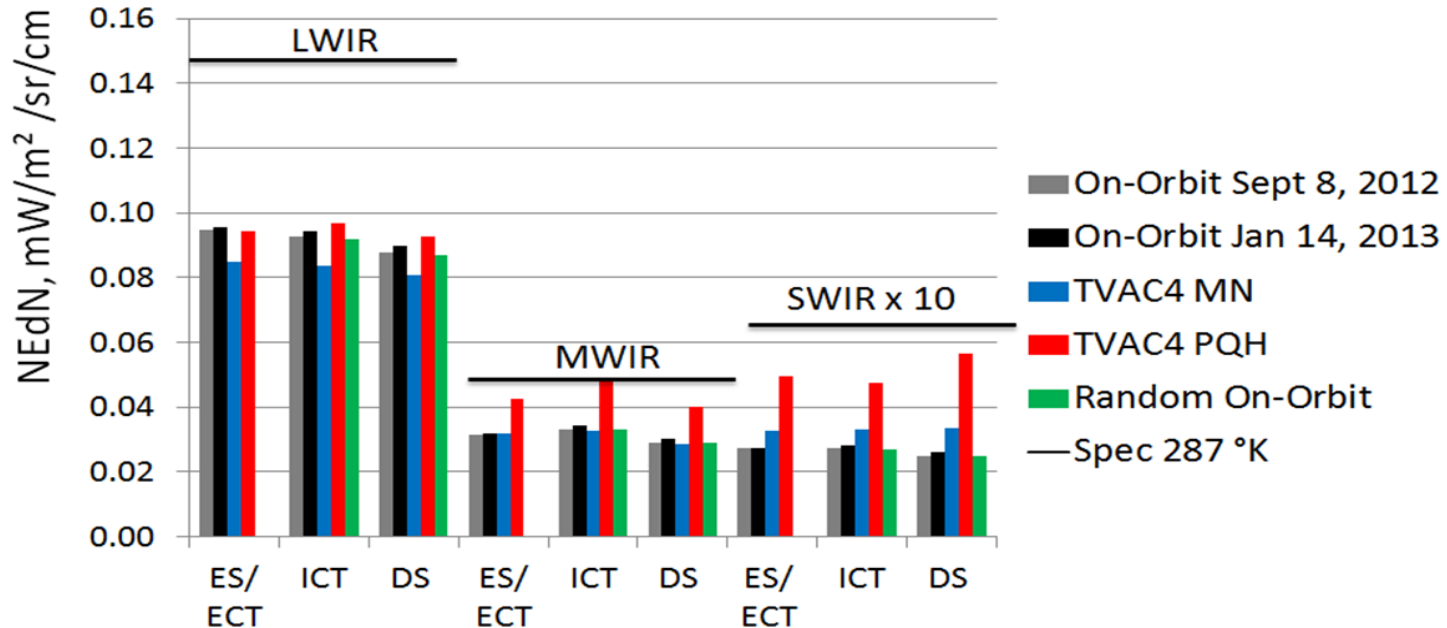
On orbit: SWIR ICT  
January 10, 2013

TVAC4 MN: SWIR ICT



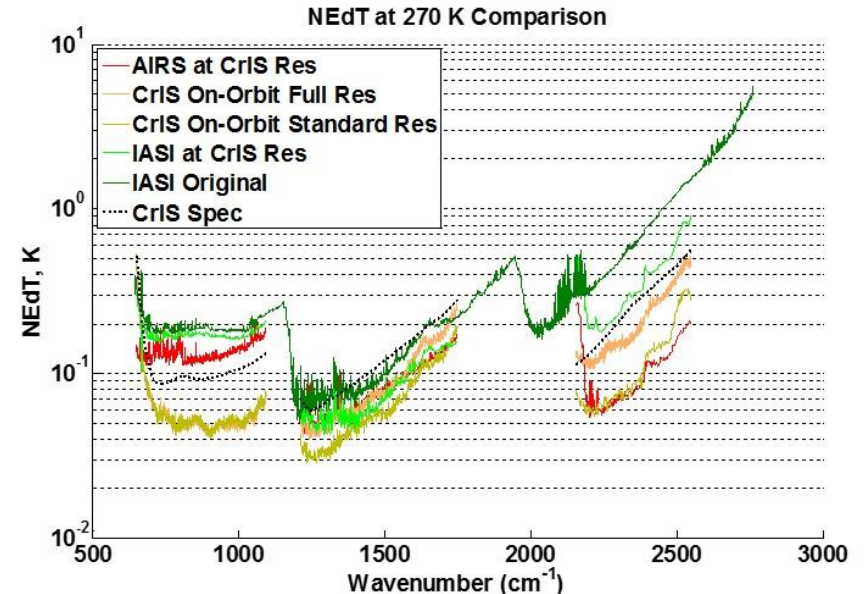
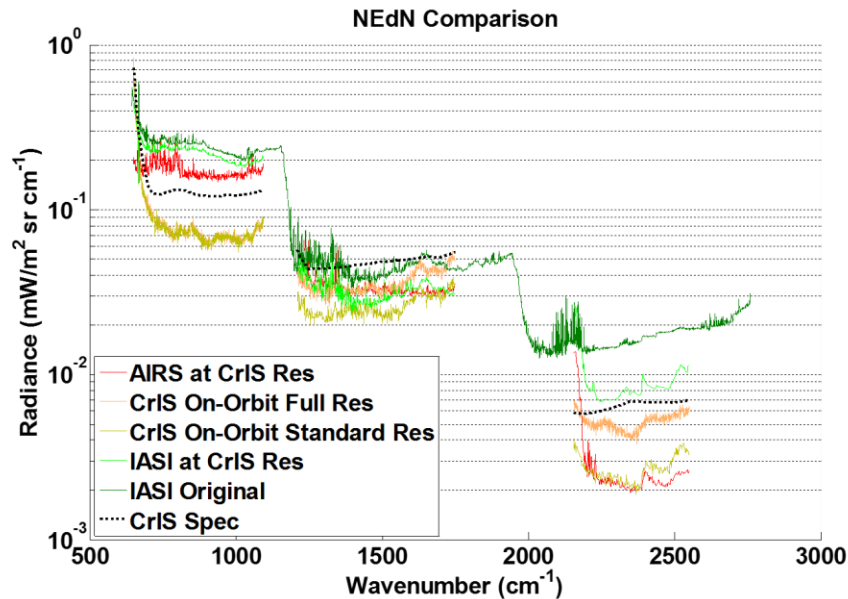
- On-orbit ICT BB target spectra exhibit practically no contribution of spectrally correlated noise
- During TVAC4 negligible contribution of spectrally correlated noise is detected

# Average real total NEdN: on-orbit vs TVAC4



- Change in the on-orbit NEdN as compared to TVAC4 MN is mostly due to a random noise component (intrinsic detector noise)
- LWIR: on-orbit random NEdN higher by ~10-12% then TVAC4 MN level
- MWIR: on-orbit NEdN is at the same level as TVAC4 MN NEdN
- SWIR: on-orbit random NEdN is smaller by ~15-20% then TVAC MN NEdN
- 220 spectra were used for each on-orbit and TVAC4 data analysis
- NEdN is averaged over each spectral band and all FOVs

# NEdN and NEdT (at 270°K) comparison with AIRS and IASI



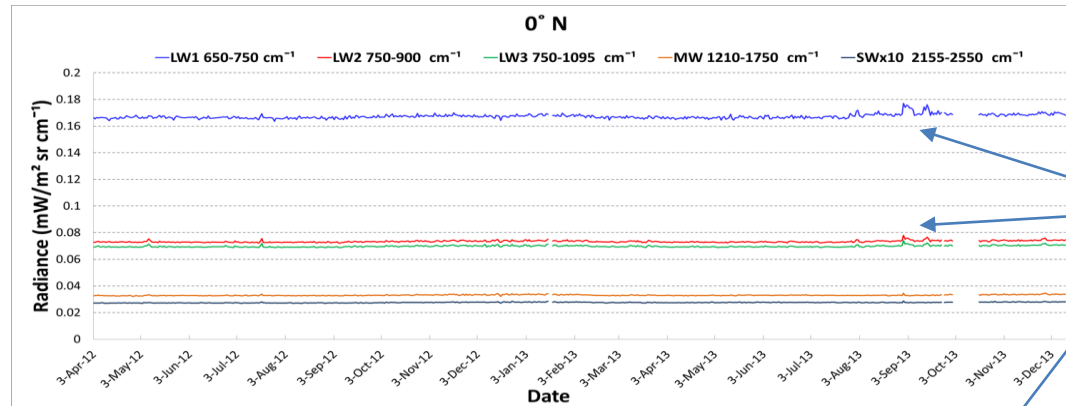
- NEdN is estimated from Earth scene radiances using SDL PCA approach (60 PCs retained)
- CrIS exhibits smaller noise level in LWIR ( $\sim x3$ ) and SWIR ( $\sim x3$ ) spectral bands than noise estimated from IASI observations reduced to CrIS spectral resolution
- As expected, CrIS full spectral resolution noise in MWIR and SWIR bands is higher by  $\sim x1.4$  and  $\sim x2$ , respectively, as compared to the CrIS standard spectral resolution



# NEdN on-orbit trend over Equator region

## ICT

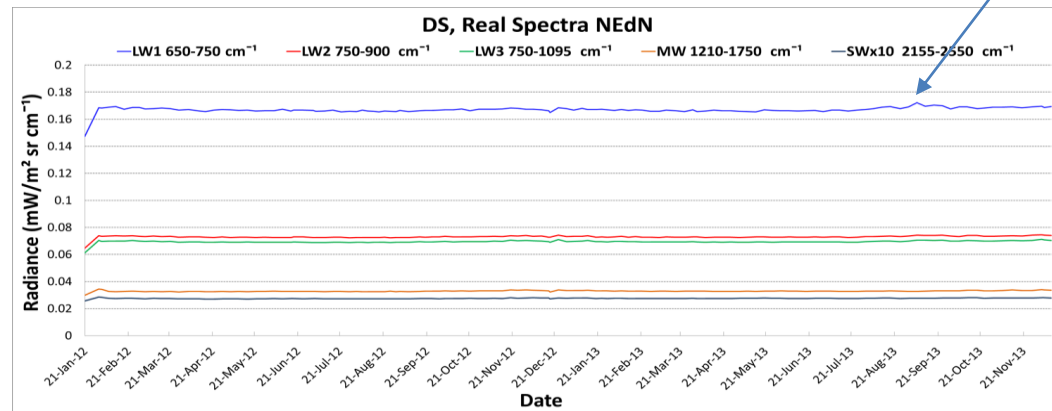
IDPS NEdN SDR  
once a day  
04/03/2012-  
11/30/2013



**LWIR FOV1  
anomaly  
observed in  
July-September  
2013**

## DS

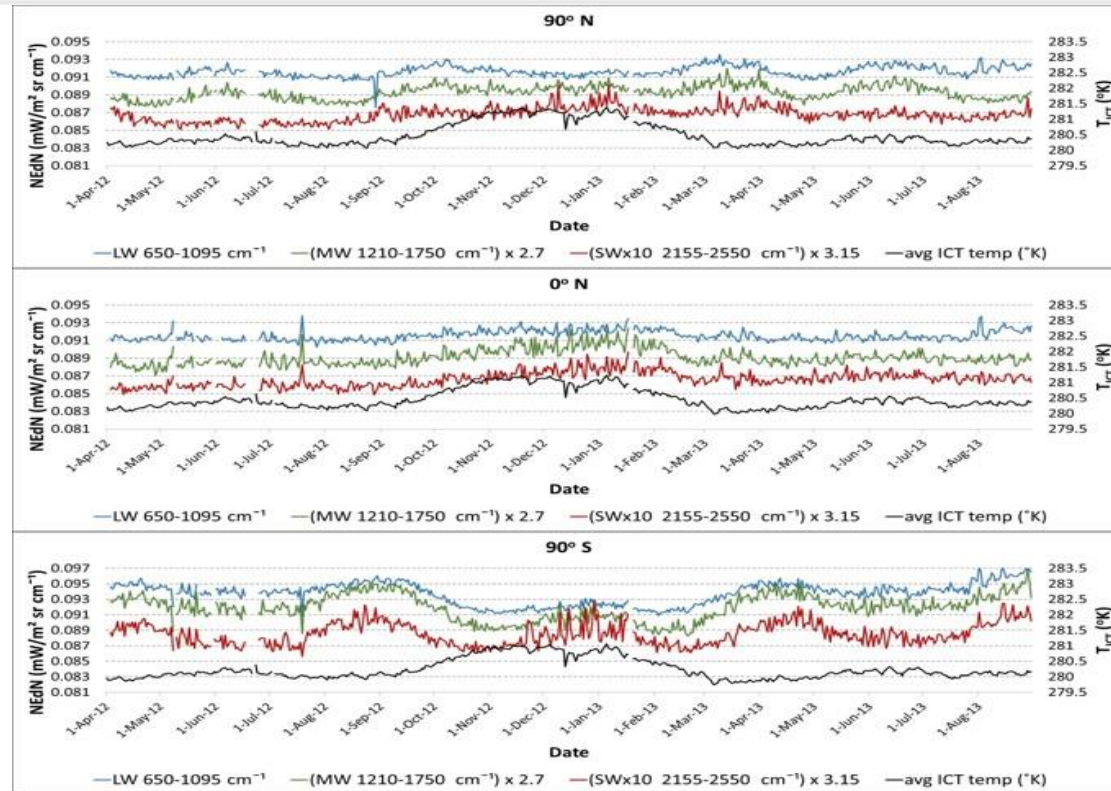
SDL monitoring  
once a week  
01/21/2012-  
11/30/2013



- NEdN remains stable during orbital operations
- LWIR FOV1 NEdN variations of  $\sim(25-50)\%$  were observed in July-September 2013
- NEdN was averaged over all FOVs and over spectral regions:

LWIR: 650-750 (beam-splitter transmittance); 750-900 (possible icing); and 750-195  $\text{cm}^{-1}$   
MWIR: Entire band 1210-175  $\text{cm}^{-1}$   
SWIR: Entire band 2155-2550  $\text{cm}^{-1}$

# Seasonal NEdN variations over NP, Equator, and SR regions



- IDPS SDR NEdN and ICT temperature acquired once a day over NP (90°N), Equator (0°N), and SP (90°S) regions
- At low latitude (~ 65° North to -65° South) the NEdN seasonal variations do not exceed 2-3% and follow the seasonal variations of the ICT temperature
- larger variations ~ 4-6% are observed over the South Pole. NEdN over both North and South Pole regions exhibit additional seasonal variations during spring and fall.

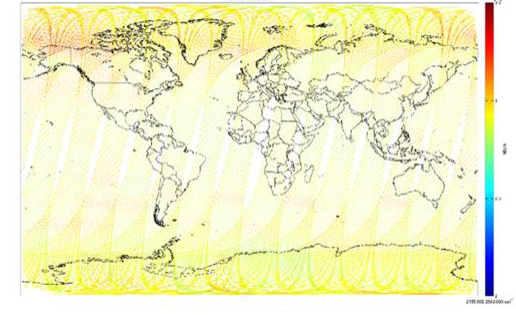
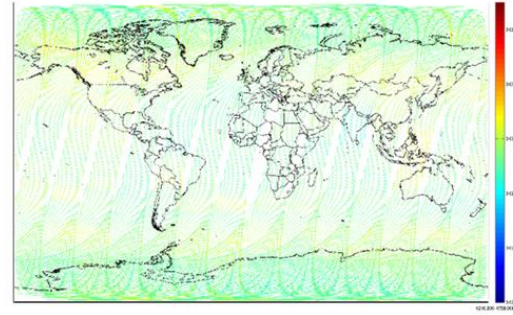
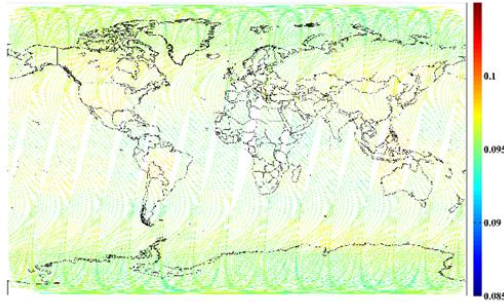
# Orbital NEdN variations, FOV5

LWIR

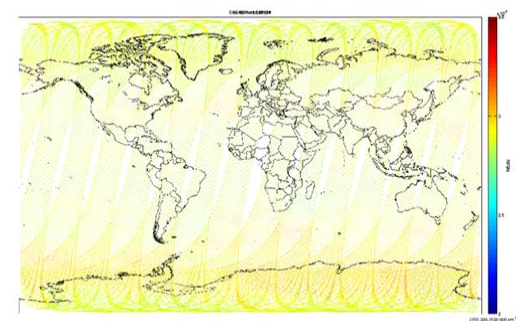
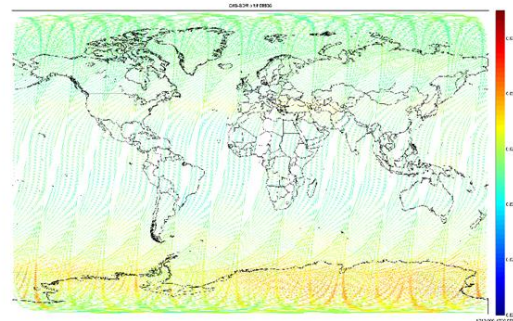
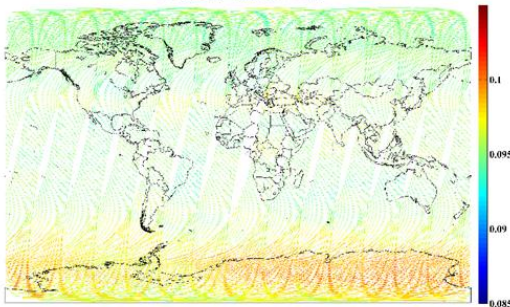
MWIR

SWIR

10 January 2013 - NEdN LW FOV 5



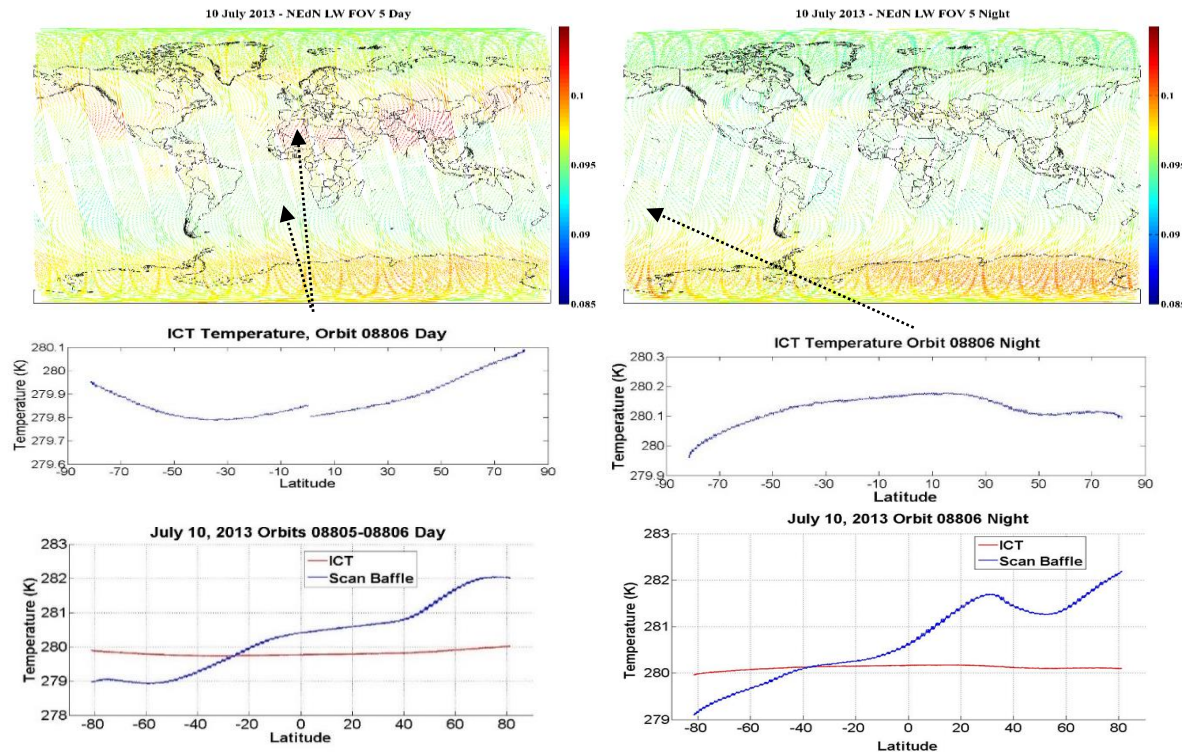
10 July 2013 - NEdN LW FOV 5



- Descending (night time ) orbits are shown
- Color scale is chosen +/- 10% of NEdN nominal values
- Small orbital NEdN variations <10% are typical for each FOV
- No NEdN anomalies are observed over the South Atlantic Anomaly region
- Relatively large area of PV HgCdTe detectors and radiation shielding provide reliable protection of the detector array from high energy particles



# Orbital NEdN variations, FOV5

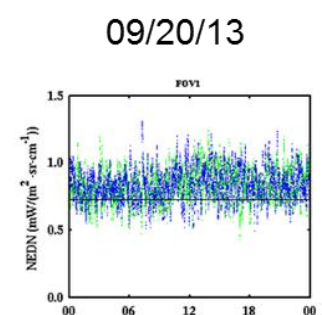
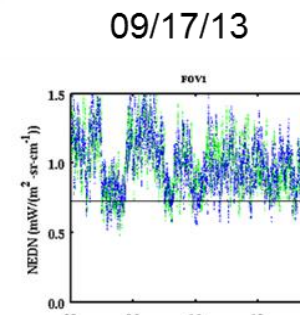
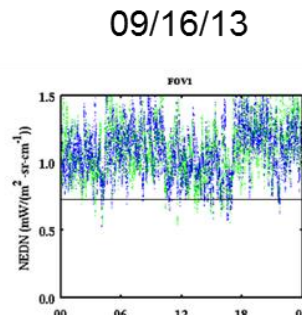
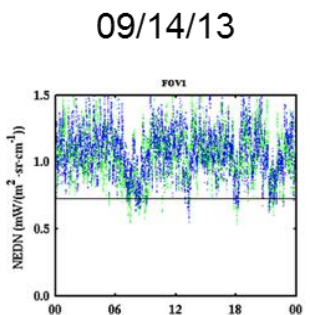
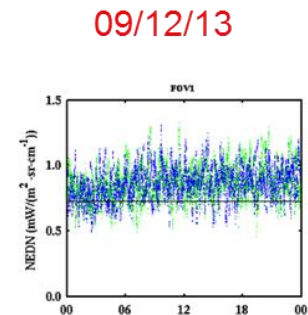
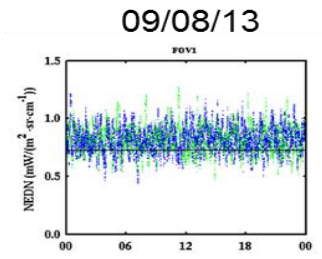
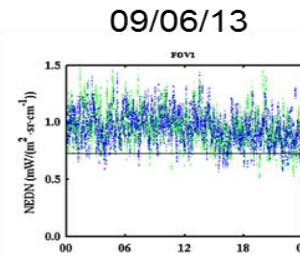
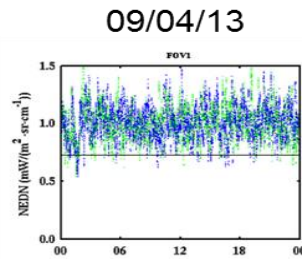
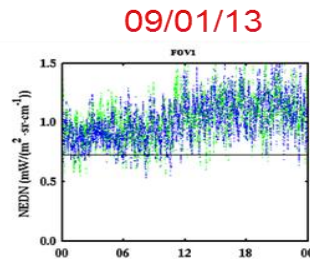
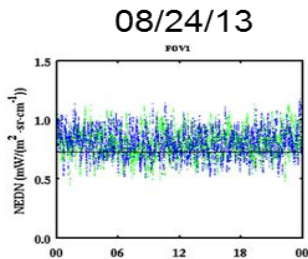
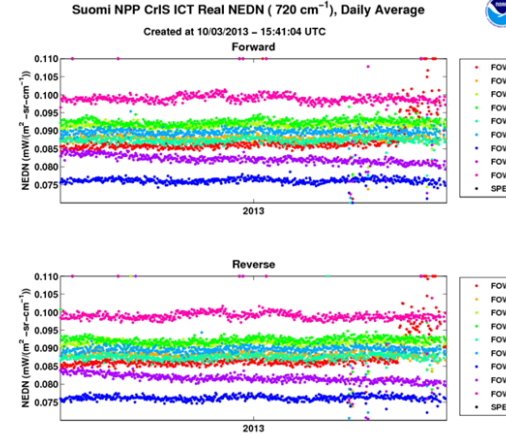
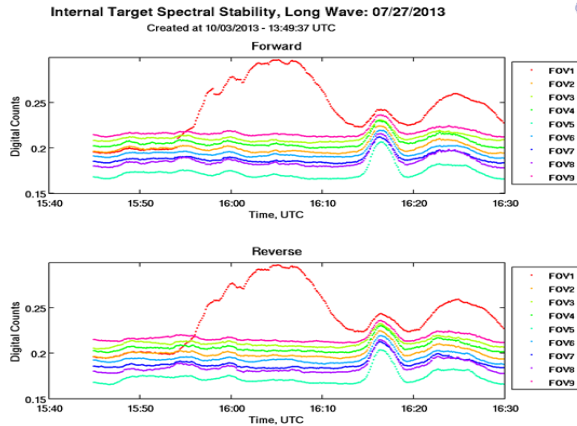


- Ascending and descending orbits are shown on July 10, 2013 with orbital variations in ICT and scan baffle temperatures for chosen orbit
- No correlation between NEdN variation and ICT and scan baffle temperatures is observed
- Transition over the North Pole always occurs from the day part of the orbit to the night part while the transition over the South Pole is night to day.
- During transition over the South Pole the sunlight hits the spacecraft about 8 min earlier than night/day transition on the Earth

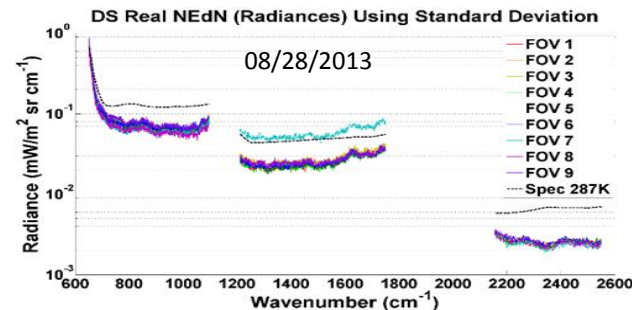
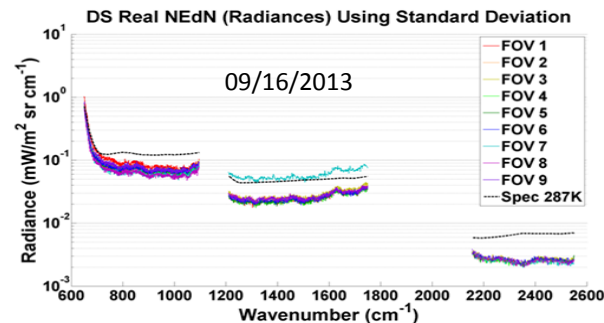
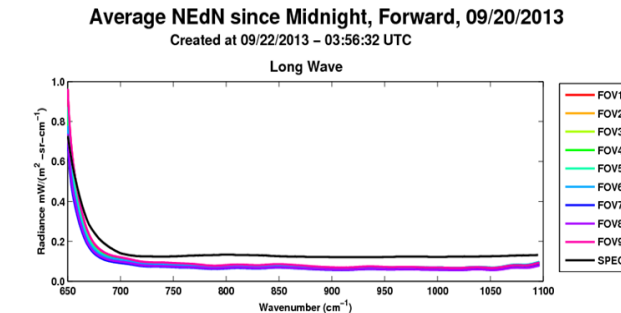
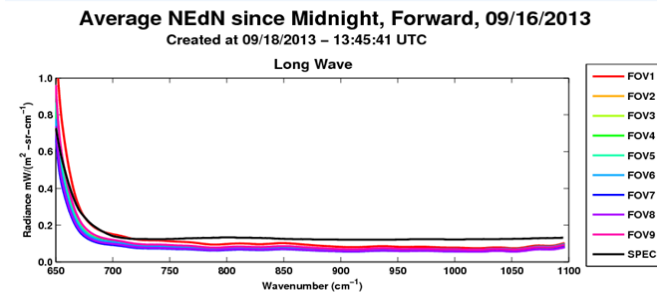
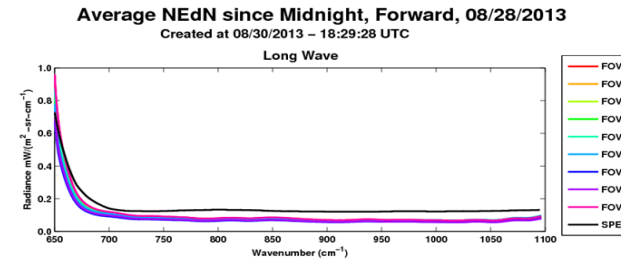
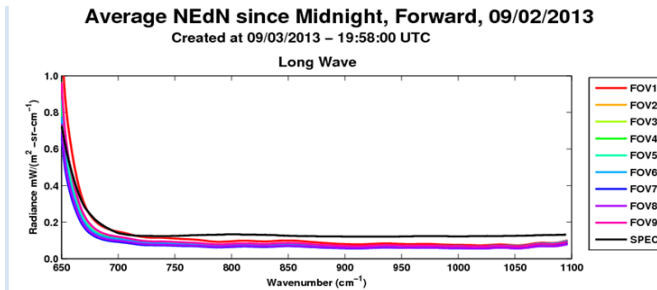


# LWIR FOV1 anomaly (1)

Three event were observed in LWIR FOV1. First event happened on **07/27/13**.



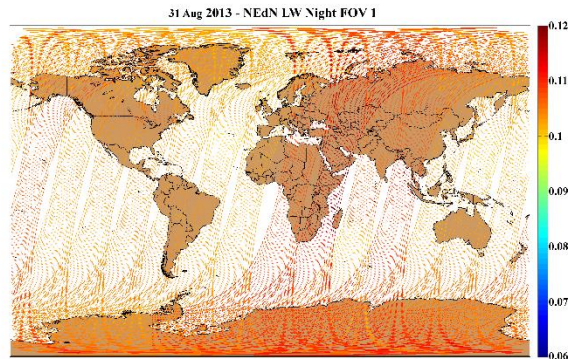
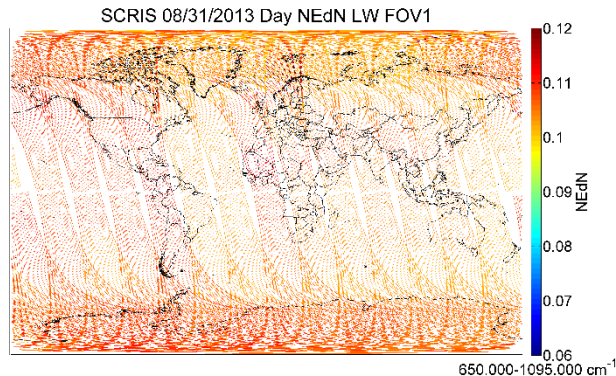
# LWIR FOV1 anomaly (2)



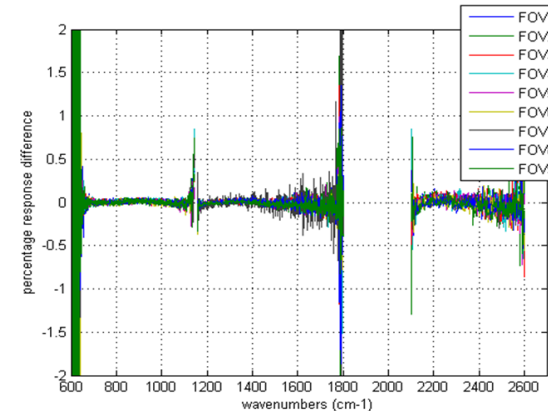
- Only LWIR FOV1 was affected
- This behavior was traced to anomalously noisy LW1 interferograms
- Excess noise transitions seen between successive interferograms
- NEdN increased ~50% in worst case and exceeds spec at several wavenumbers

# LWIR FOV1 anomaly (3)

## LWIR FOV1 orbital variations 08/31/2013



## Relative FOV response (gain) changes in percent on 09/02/2013 with respect to 08/25/2013



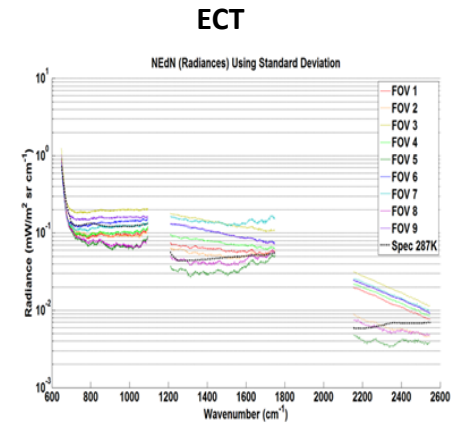
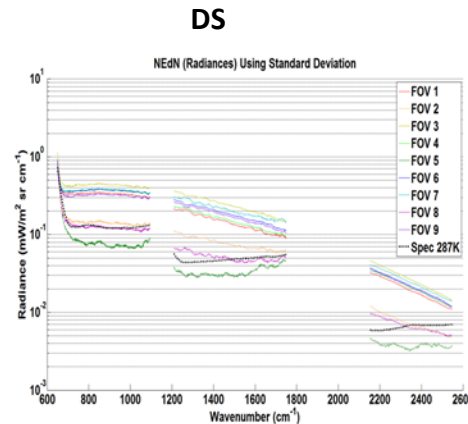
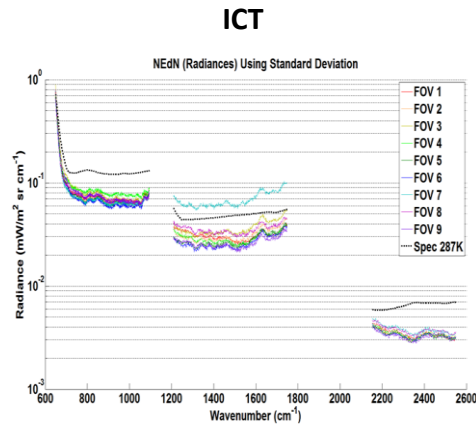
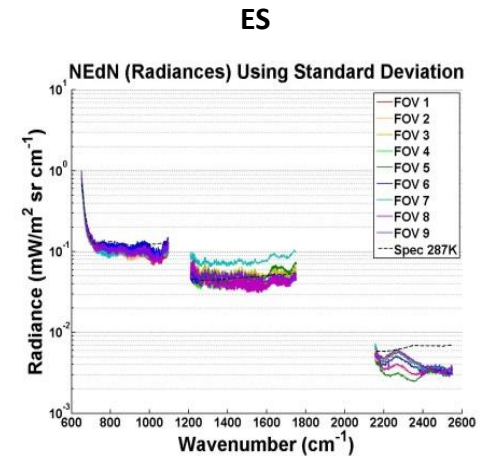
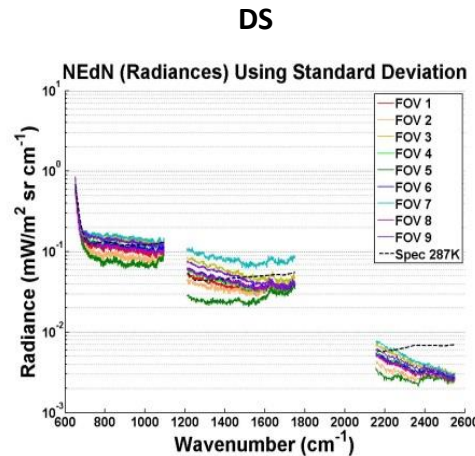
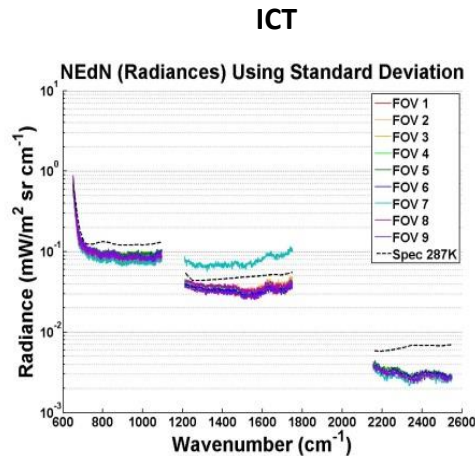
- LW FOV 1 shows no response (gain) anomaly and is within family with other FOVs
- Increase in LWIR FOV1 NEdN is observed for all orbits during LWIR FOV1 anomaly events
- No bit trim, impulse, FCEs, etc. present in data
- No high particles anomalies are seen in S/C data

- CrIS SDR data is not marked as degraded or invalid
- LWIR FOV1 noise went back in-family and has remained stable since 09/25/2013
- SDR team continue to investigate root cause of the LWIR FOV1 anomaly
- If anomaly is observed CrIS will be commanded to dwell in the diagnostic mode

# Total Imaginary NEdN

## On-orbit vs TVAC4 MN

Orbit 6245  
January 10, 2013

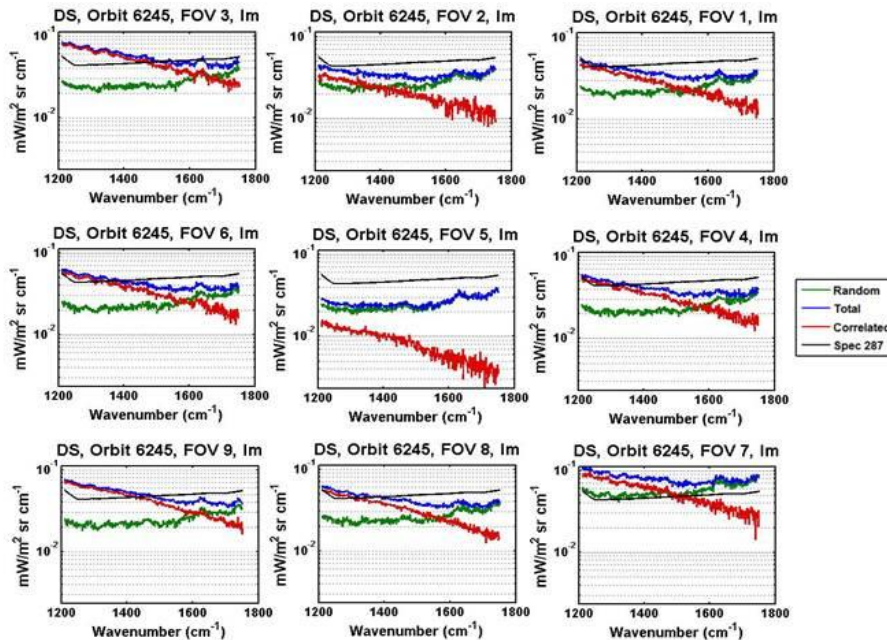


TVAC4 MN

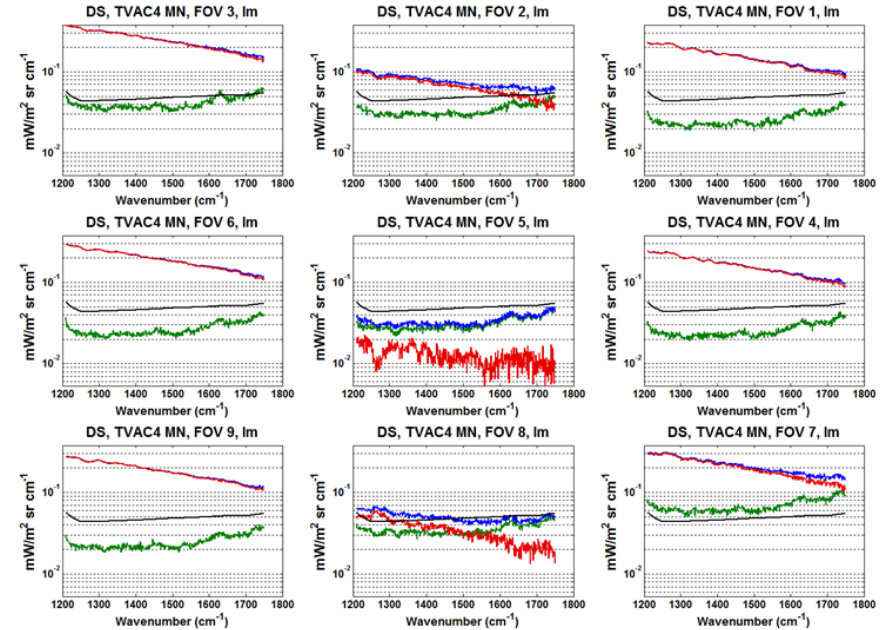
- Imaginary NEdN exhibits elevated level due to the spectrally correlated noise component
- Random noise is dominated by the intrinsic detector noise like in real NEdN
- On-orbit imaginary NEdN is lower than during TVAC4 especially for DS derived NEdN



DS: Orbit 6245, January 10, 2013

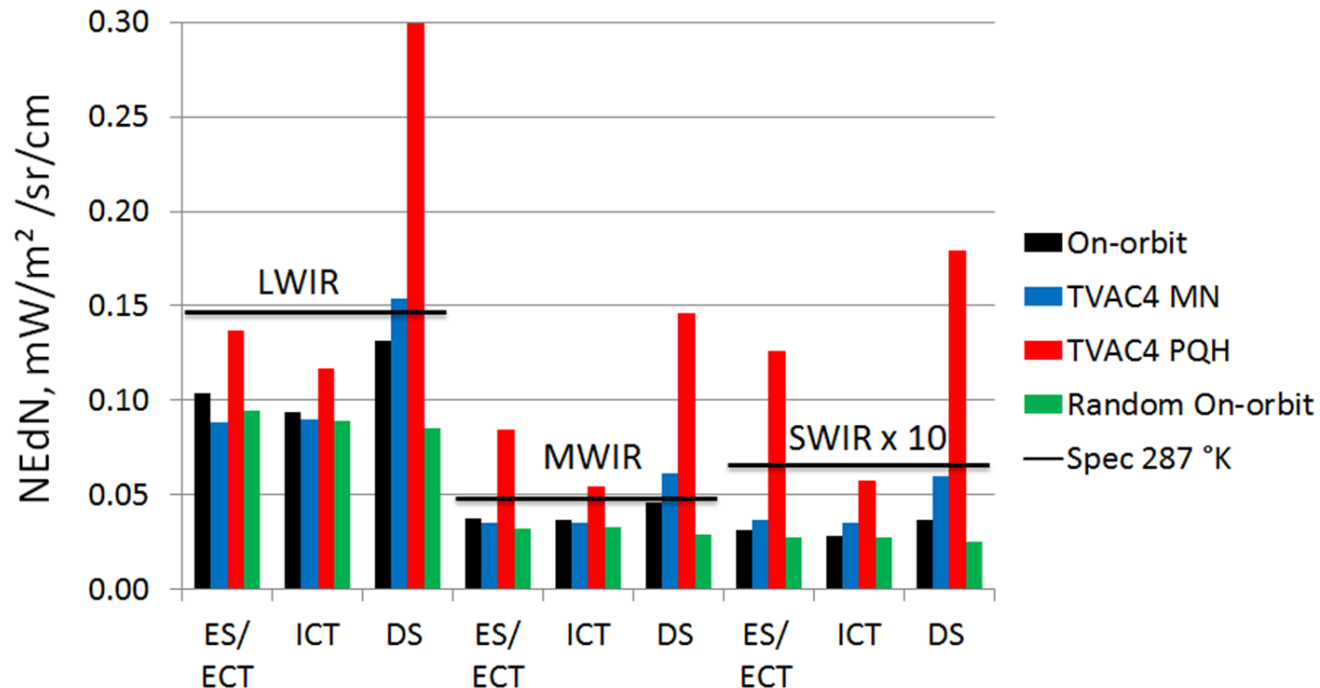


DS: TVAC4 MN



- Imaginary NEdN is extremely sensitive to any instrument artifacts and external vibration as compared to real NEdN.
- Corner FOVs are more susceptible to the tilt-induced OPD sample jitter
- DS derived imaginary NEdN has largest vibration sensitivity while ICT target exhibits the smallest vibration susceptibility.
- On-orbit correlated imaginary NEdN significantly lower than during TVAC4

# Average **imaginary total NEdN**: on-orbit and TVAC4 comparison

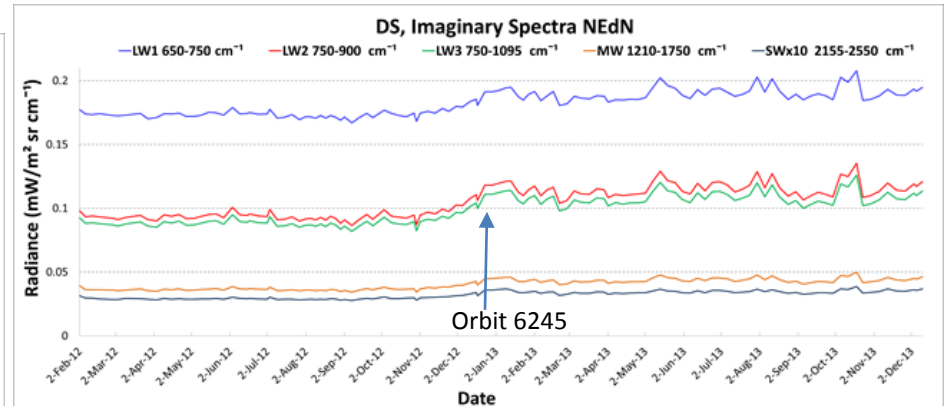
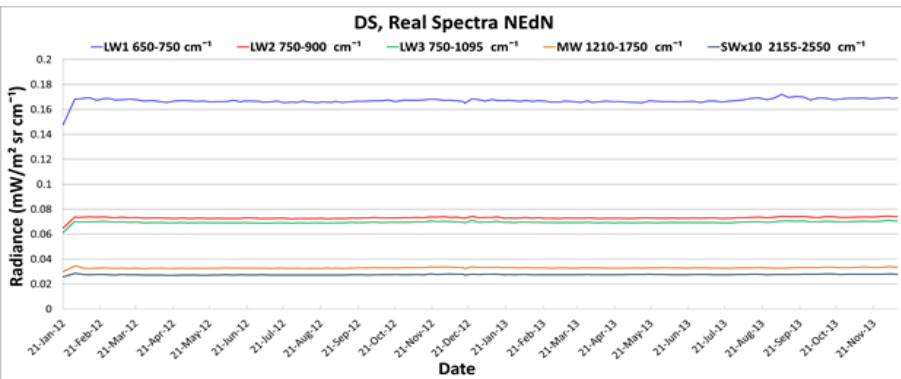


- On-orbit data : orbit # 6245 at January10, 2013 (max increase in the imaginary NEdN)
- During TVAC4 PQH test additional vibration from the test equipment was present
- On-orbit imaginary NEdN is comparable or smaller than TVAC4 MN value
- Only random NEdN component can be estimated on-orbit from ES view using PCA

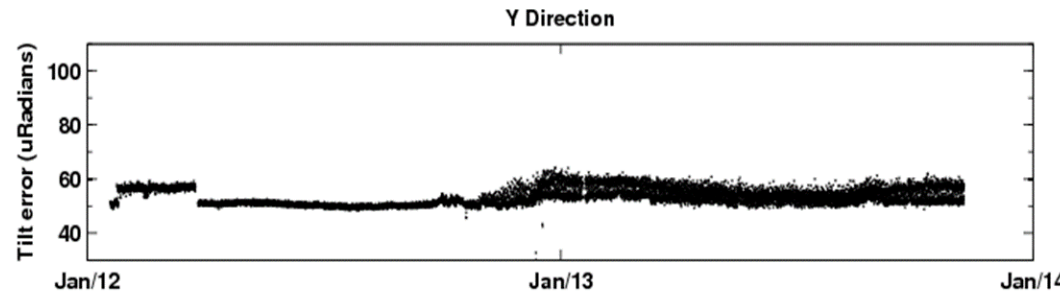
# DS derived average **imaginary NEdN**

Real spectra NEdN

Imaginary spectra NEdN

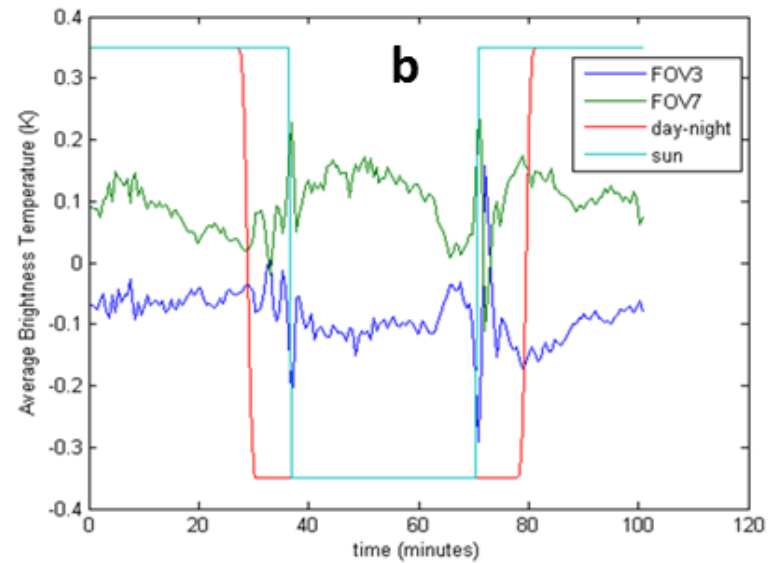
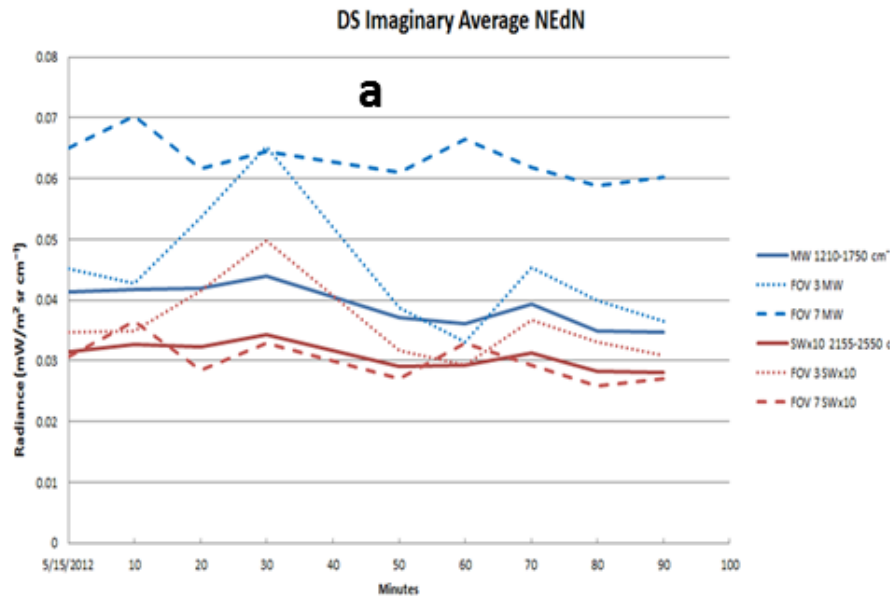


STAR NPP CrIS Housekeeping  
DA tilt error in Y-direction,  
hourly averaged



- NEdN has increased in the imaginary part of the DS spectra in all spectral bands (~30-40%)
- Increase in the imaginary DS NEdN correlates with DA tilt error in Y-direction
- Practically no change in real spectra NEdN is observed
- Possible source of small additional S/C vibration: ATMS scanning assembly

# Orbital fluctuations in the DS imaginary NEdN



- DS imaginary NEdN exhibit slightly larger fluctuations ~10-30% over time as compared to the real NEdN and ICT derived NEdN (a)
- Variation are due to correlated noise component
- Larger noise occurs near North and South poles when the Sun light hit the Suomi NPP spacecraft during day/night transition (flight time of ~25 and ~80 minutes respectively)
- These variations in the imaginary NEdN correlate with FOV-to-FOV responsivity and small variations in BT of FOV3 and FOV7 (b)



# Conclusion

1. NEdN level meets mission requirements with a large margin of typically 100% (except MWIR FOV 7) and is consistent with ground test results.
2. The intrinsic detector noise randomly distributed in spectral domain dominates total instrument NEdN. Negligible contribution of correlated noise is observed.
3. CrIS has comparable or smaller noise levels than AIRS and IASI heritage instruments ( $\sim 2$ -3 times smaller in LWIR spectral band)
4. NEdN has remained extremely stable during on-orbit operations. Only small seasonal, orbital and spatial NEdN variations ( $< 10\%$ ) are observed on-orbit.
5. Small anomaly ( $\leq 50\%$ ) in LWIR FOR1 NEdN was observed on July 07 and September 10 and 12, 2013. Remains stable on slightly elevated level ( $< 10\%$ )
6. CrIS full spectral resolution noise in MWIR and SWIR bands is higher by  $\sim x1.4$  and  $\sim x2$ , respectively, as compared to the CrIS standard spectral resolution.
7. Imaginary NEdN is extremely sensitive to any instrument artifacts and external vibration as compared to the real NEdN and may serve as an important tool to monitor on-orbit performance of CrIS